AD-A256 183

(2)

TECHNICAL REPORT RD-WS-92-11

OPTICAL PHASE ABERRATORS FOR POSSIBLE USE AS PROTECTIVE EYEWARE

Travis S. Taylor
Wayne E. Davenport
Stanley P. Patterson

Weapons Sciences Directorate
Research, Development, and Engineering Center

JUNE 1992

U.S. ARMY MISSILE COMMAND
Redstone Arsenal, Alabama 35898-5000

Approved for public release; distribution is unlimited.

DISPOSITION INSTRUCTIONS

DESTROY THIS REPORT WHEN IT IS NO LONGER NEEDED. DO NOT RETURN IT TO THE ORIGINATOR.

DISCLAIMER

THE FINDINGS IN THIS REPORT ARE NOT TO BE CONSTRUED AS AN OFFICIAL DEPARTMENT OF THE ARMY POSITION UNLESS SO DESIGNATED BY OTHER AUTHORIZED DOCUMENTS.

TRADE NAMES

USE OF TRADE NAMES OR MANUFACTURERS IN THIS REPORT DOES NOT CONSTITUTE AN OFFICIAL INDORSEMENT OR APPROVAL OF THE USE OF SUCH COMMERCIAL HARDWARE OR SOFTWARE.

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1a. REPORT SECURITY CLASSIFICATION Unclassified	1b. RESTRICTIVE MARKINGS
2a. SECURITY CLASSIFICATION AUTHORITY	3. DISTRIBUTION/AVAILABILITY OF REPORT *Approved for Public Release; Distribution is Unlimited.*
2b. DECLASSIFICATION/DOWNGRADING SCHEDULE	
4. PERFORMING ORGANIZATION REPORT NUMBER(S) Technical Report RD–WS–92-11	5. MONITORING ORGANIZATION REPORT NUMBER (S)
6a. NAME OF PERFORMING ORGANIZATION Weapons Sciences Directorate RD&E Center 6b. OFFICE SYMBOL (if applicable) AMSMI-RD-WS-LS	7a. NAME OF MONITORING ORGANIZATION
6c. ADDRESS (City, State, and ZIP Code) Commander, U. S. Army Missile Command ATTN: AMSMI–RD–WS–LS Redstone Arsenal, AL 35898–5248	7b. ADDRESS (City, State, and ZIP Code)
8a. NAME OF FUNDING/SPONSORING ORGANIZATION 8b. OFFICE SYMBOL (if applicable)	9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER
8c. ADDRESS (City, State, and ZIP Code)	10. SOURCE OF FUNDING NUMBERS PROGRAM ELEMENT NO. | PROJECT NO. | TASK NO. | WORK UNIT ACCESSION NO.

11. TITLE (Include Security Classification)

OPTICAL PHASE ABERRATORS FOR POSSIBLE USE AS PROTECTIVE EYEWARE

12. PERSONAL AUTHOR(S)

Travis S. Taylor, Wayne E. Davenport, and Stanley P. Patterson

13a. TYPE OF REPORT	13b. TIME COVERED	14. DATE OF REPORT (Year, Month, Day)	15. PAGE COUNT
Summary	FROM June 88 TO June 92	June 1992	17

16. SUPPLEMENTARY NOTATION

17. COSATI CODES			18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number)
FIELD	GROUP	SUB-GROUP	Protective Eyeware, Phase Aberrators, Vision, Filters, Lasers

19. ABSTRACT (Continue on reverse if necessary and identify by block number)

Current methods of eye protection consist mostly of band-pass filters which will only pass a given small band of the visible and/or near visible spectrum. It is possible to design protective eyeware for the entire visible region which will not disrupt the user's vision too much for certain tasks where visual acuity is essential, such as flying an aircraft. This report documents the results of experiments undertaken to design protective eyeware for use in working with visible laser radiation. During this research many types of phase aberrators were constructed and tested. Aberrators were made from materials ranging from simple items such as cellophane tape and wet tissue paper, to more exotic materials such as ethanol and water placed between glass plates. Preliminary experiments demonstrate that the intensity of a laser beam at the Fourier transform plane can be greatly reduced by placing a phase aberrator in the optical path before the transform lens. It was also discovered that phase aberrators can be designed which do not impair one's vision more than is acceptable for certain tasks where visual acuity is essential. These results offer some promise in the possibility of successfully designing laser protective eyeware that will effectively reduce the possibility of serious eye damage due to a laser beam being focussed on the retina. Also, a major advantage of phase aberrator type protective eyeware is that it would be effective over the entire visible spectrum, not just small portions of the spectrum as is the case with existing eyeware.

20. DISTRIBUTION/AVAILABILITY OF ABSTRACT ☐ UNCLASSIFIED/UNLIMITED ☒ SAME AS RPT. ☐ DTIC USERS	21. ABSTRACT SECURITY CLASSIFICATION Unclassified	
22a. NAME OF RESPONSIBLE INDIVIDUAL Travis S. Taylor	22b. TELEPHONE (Include Area Code) (205) 876-8184	22c. OFFICE SYMBOL AMSMI-RD-WS-LS

DD Form 1473, JUN 86 Previous editions are obsolete.

SECURITY CLASSIFICATION OF THIS PAGE
Unclassified

TABLE OF CONTENTS

LIST OF FIGURES

I. INTRODUCTION

When the eye is exposed to visible laser radiation, the lens of the eye will focus the beam into a tiny area on the retina and serious damage may occur. Current methods of eye protection consist mostly of band-pass filters which will not pass a given small band of the visible and/or near visible spectrum. For example, protective eyeware for doubled Neodymium:YAG (Nd:YAG) lasers will not transmit green light (532 nm wavelength) but will allow other wavelengths such as red or orange light to transmit. Hence, if there is more than one laser firing in a given environment, more than one set of band-pass filters will be required. This means that a multi-wavelength or broad-band filter would be required. However, if such a filter is used, the entire visible spectrum would be attenuated to a point at which its user would not be able to see because no visible light would be transmitted through it.

It is possible to design protective eyeware for the entire visible region which will not disrupt the user's vision too much for certain tasks where visual acuity is essential (such as flying an aircraft) [1]. One possible approach to this problem is the production of an optical element that creates a desired amount of blurriness due to careful control of phase perturbations, which in turn will lower the power density at the retina diffraction limit spot (see Figure 1). For example, a window screen does not affect one's visual acuity much, but it does attenuate a plane-wave incident upon it a certain amount. Also, after passing through the screen and being Fourier transformed by the lens of the eye onto the retina (where the retina is the transform plane) the plane wave can be seen to be an even distribution of a sinc^2 function convolved with a comb function. Its power density is less than that of an airy disc pattern which the original plane wave would image at the transform plane (see Figure 2).

During this research many types of phase aberrators were constructed and tested. Aberrators were made from materials ranging from simple items such as cellophane tape and wet tissue paper, to more exotic materials such as ethanol and water placed between glass plates.

The most successful phase aberrator was constructed from a glass slide etched with a hydrofluoric acid and water solution. Various etching techniques and concentrations of acid were used until a desirable product was created. Preliminary experiments demonstrated that the acid etched aberrator would reduce the intensity at the diffraction limit spot of the eye by a factor of more than two. However, it also caused significant vision disruption bordering on the maximum amount of blurriness that is acceptable for certain tasks where visual acuity is essential.

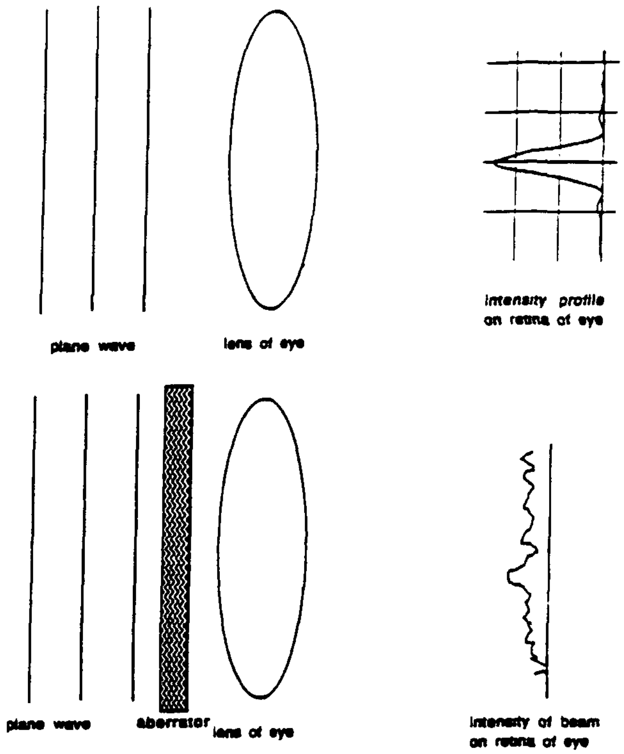

Figure 1. With the Phase Aberrator in Front of the Eye, the Plane Wave Laser Beam Incident on it is Distorted to a Safer Level of Intensity

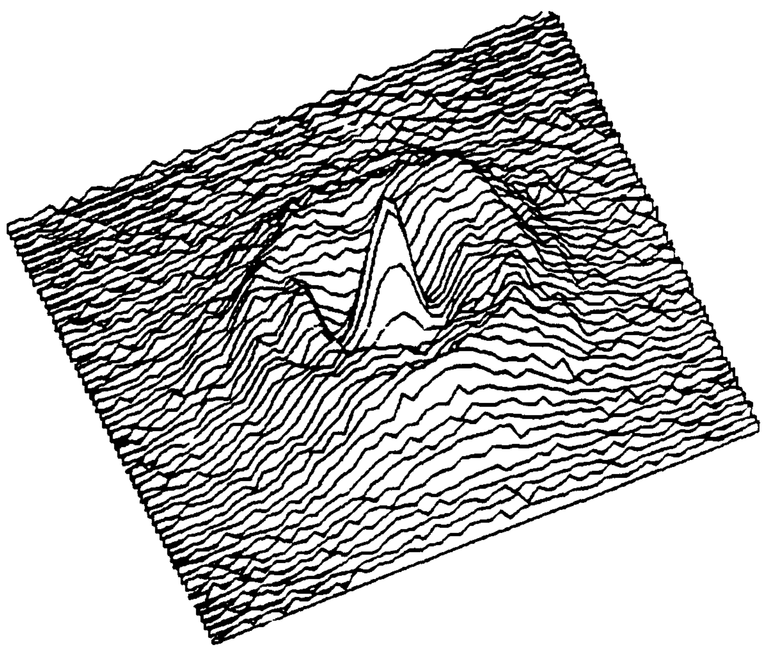

Figure 2a. Image of a Plane Wave at the Fourier Transform Plane

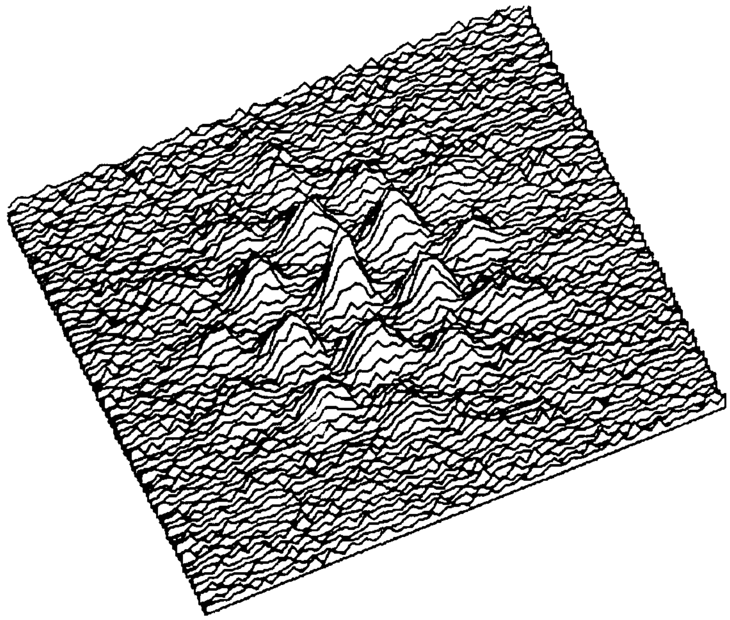

Figure 2b. Image of a Plane Wave After Passing Through a Screen Filter at the Fourier Transform Plane

II. VARIOUS ABERRATOR DESIGNS

As seen in Figure 2, a filter that consists of a screen will create a diffraction pattern in the transform plane that has a lower power density than that of a plane wave at the transform plane. It was decided to measure the attenuation per square centimeter in the far field due to two types of screen filters. One can be described as comb(x,y)rect(x/.1,y/.1) cm^{-1} and the other as comb(x,y)circ(1/.05) cm^{-1}. In other words, one screen had square holes in it about 1 mm by 1 mm in size and the other had circular holes in it about 1 mm in diameter. An optical setup was designed to demonstrate what a particular input beam would look like at the diffraction limit spot on the retina of the eye. This optical arrangement (see Figure 3) consisted of a lens of a given focal length focused onto the focal plane of a second lens with a slightly larger focal length. The second lens was used simply to enlarge the transform plane of the first lens and image it onto a power meter a few meters away. Without the comb filters the relative power at the transform plane was measured as 1.45 + .01 units. With the comb filters, the power was measured to be .95 + .01 units. The percent attenuation was then calculated as 1–(.95/1.45) + .02. Thus, the attenuation due to the screen or comb filters was found to be 34.5 + 2 percent.

Figures 4, 5, and 6 are the spatial profiles of the diffraction limit spot of the unperturbed beam, and the rectangular and circular holed beams, respectively. The profiles were measured using a video camera, framegrabbing hardware, a Macintosh IIci, and respective software. A Helium-Neon laser was collimated and passed through a lens and an iris as shown in Figure 3. The video camera

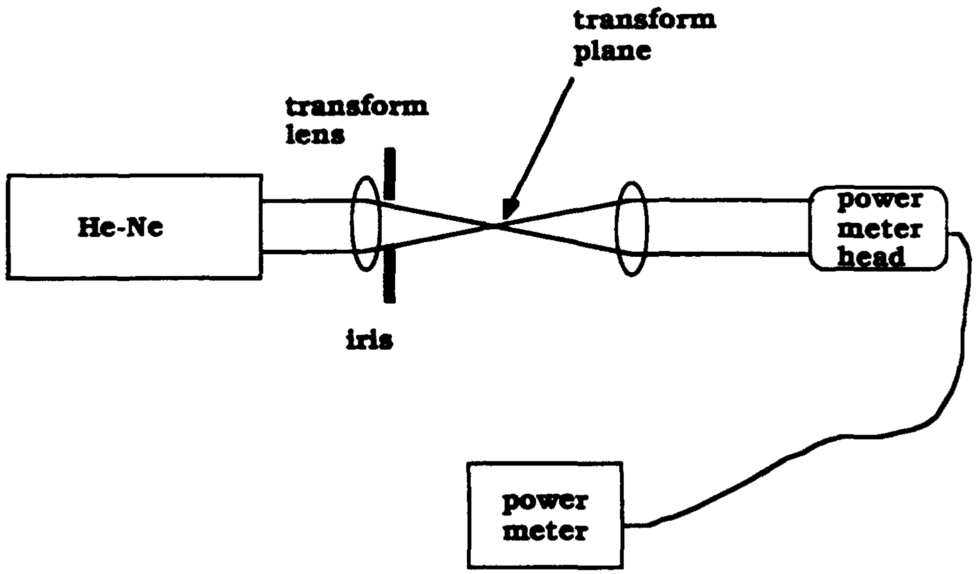

Figure 3. Optical System Utilized to Simulate the Eye and Measure Laser Beam Intensities at the Retinal Plane

was then focused on the transform plane of the lens. Note that Figure 4 is the typical $sinc^2(x,y)$ function that would be expected from taking the Fourier transform of a plane wave. Figures 5 and 6 are the profiles of the screen filtered plane wave. As expected, the image at the retina can be described by $sinc^2(x,y)$**comb(x,y) [2,3], which has a lower power density than that in Figure 4.

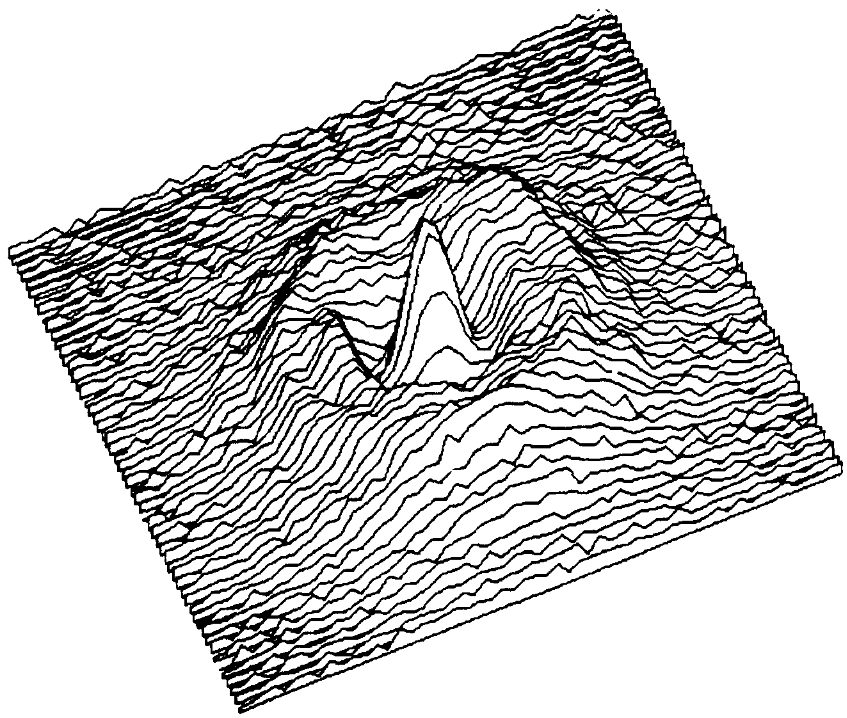

Figure 4. Image of Plane Wave on Retina

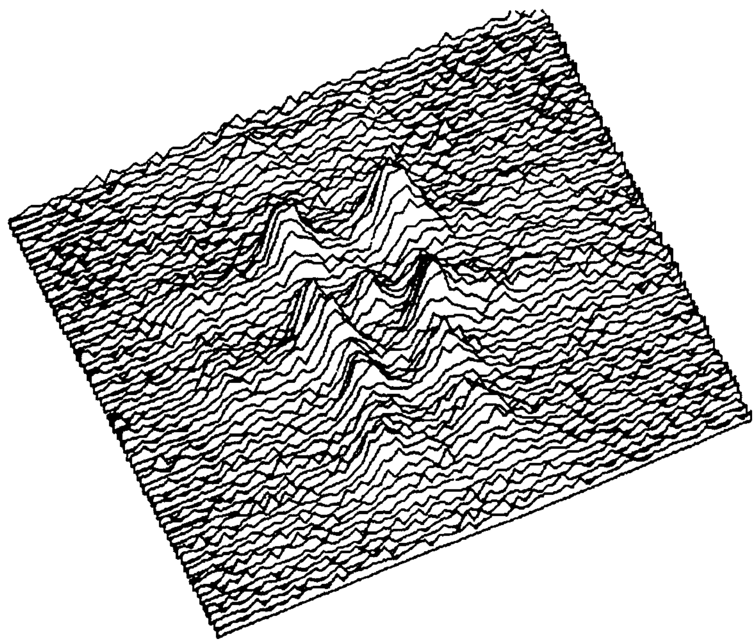

Figure 5. Image on Retina After Passing a Plane Wave Through a Rectangular Hole Screen Filter

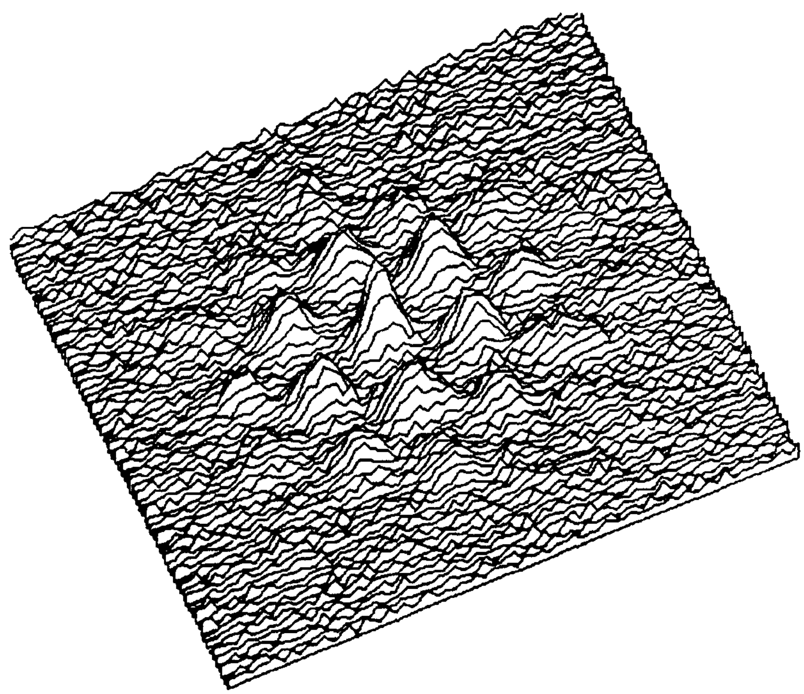

Figure 6. Image on Retina After Passing a Plane Wave Through a Circular Hole Screen Filter

Other materials tried as phase aberrators were tested. The best results came from aberrators made of etched glass. Glass slides were etched with various concentrations of hydrofluoric acid (HF) and water solutions. Certain methods have been found to be beneficial to implement during the etching process. In the processes used, 24 percent HF in water was found to etch the glass sufficiently. Any greater concentration of the HF appeared to etch the glass in an uncontrollable manner, which is undesirable for this process. By applying acid in a nonuniform thickness, tiny rivulets are etched in the glass. These rivulets produce considerable wavefront perturbation to the plane wave laser light. In order to control the production of these rivulets, the glass slide was dipped into the HF/water solution for 1 second, removed for 10 seconds, and then dipped again for 1 second. The process was repeated as many times as necessary to achieve desired results. It was found that the best results occurred after 15 of the dip and drying sequences. Figure 7 is the spatial profile of a plane wave passing through the 15-dip etched filter, measured as before at the transform plane. Note the random distribution of intensity.

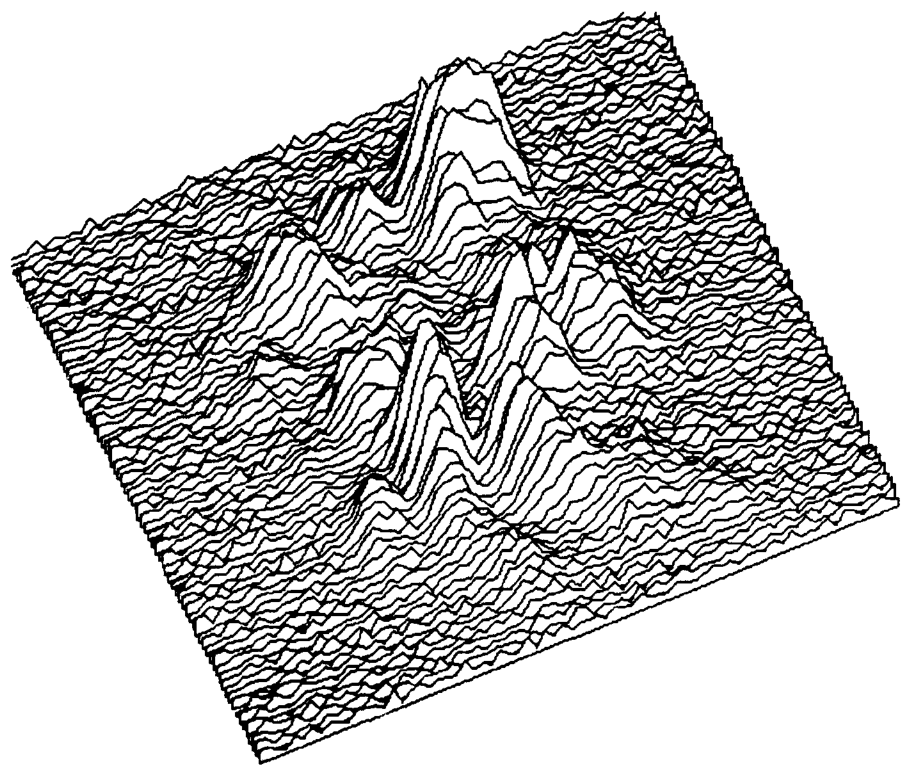

Figure 7 Image on Retina After Passing a Plane Wave Through "Dip" Etched Filter

Another etching technique used was also found to be beneficial. By masking a glass slide with a circular holed screen and then submerging it in the acid solution, an aberrator with an index of refraction of n(x,y)=comb(x,y)circ(x,y) was created. Figure 8 is the spatial profile at the transform plane of a plane wave aberrated by this filter.

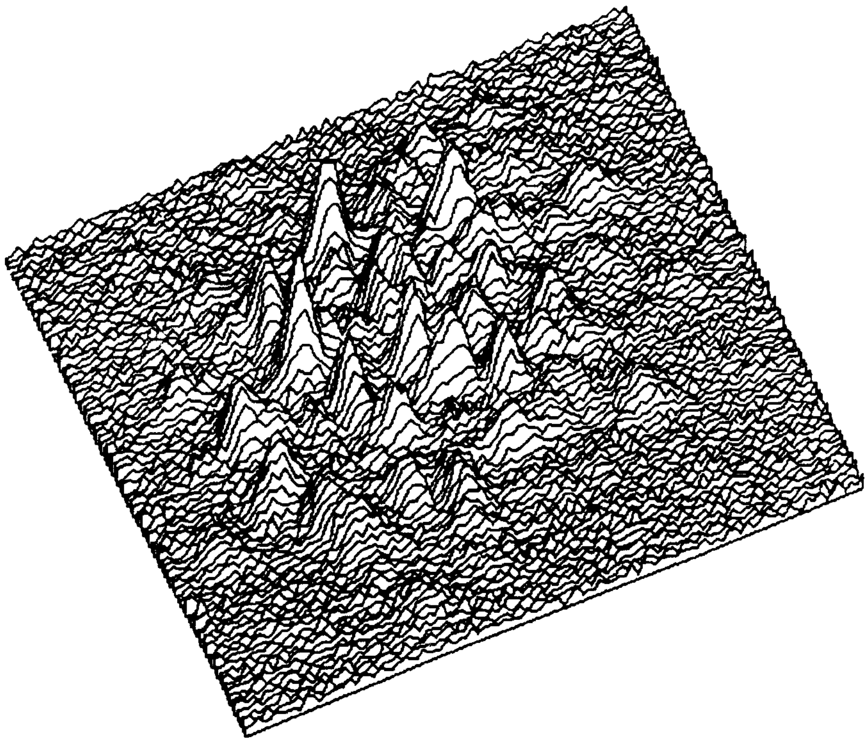

Figure 8. Image on Retina After Passing a Plane Wave Through a Filter Where n(x,y) = comb (x,y) circ (x,y)

III. VISUAL ACUITY DATA

In order for the filters to be useful they must distort any incoming laser beam without greatly distorting the user's vision. Figure 9 is the spatial profile of a target reading "LASER STANDING OPERATING PROCEDURES". Figures 10 – 13 are profiles of the same target with different filters. Figures 10 and 11 are profiles of the target with the screen filters in front of the camera lens. Note that the target is uniformly distorted and attenuated; however, it is still possible to read the target. Figures 12 and 13 show the target with the etched filters in front of the camera lens. It is still possible to read the target and there is very little, if any, attenuation caused by these filters.

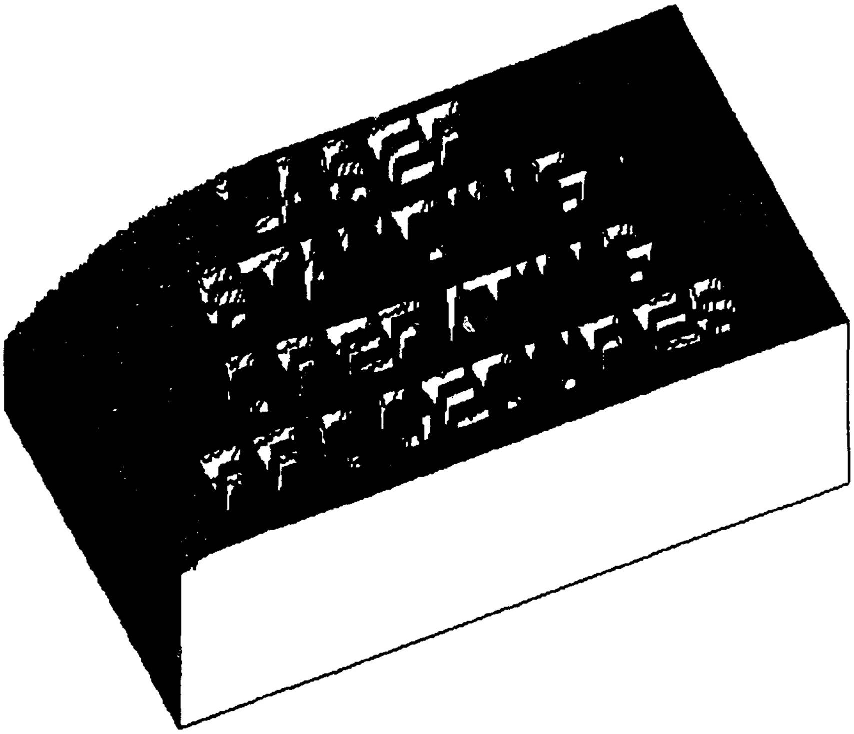

Figure 9. Spatial Profile of Target

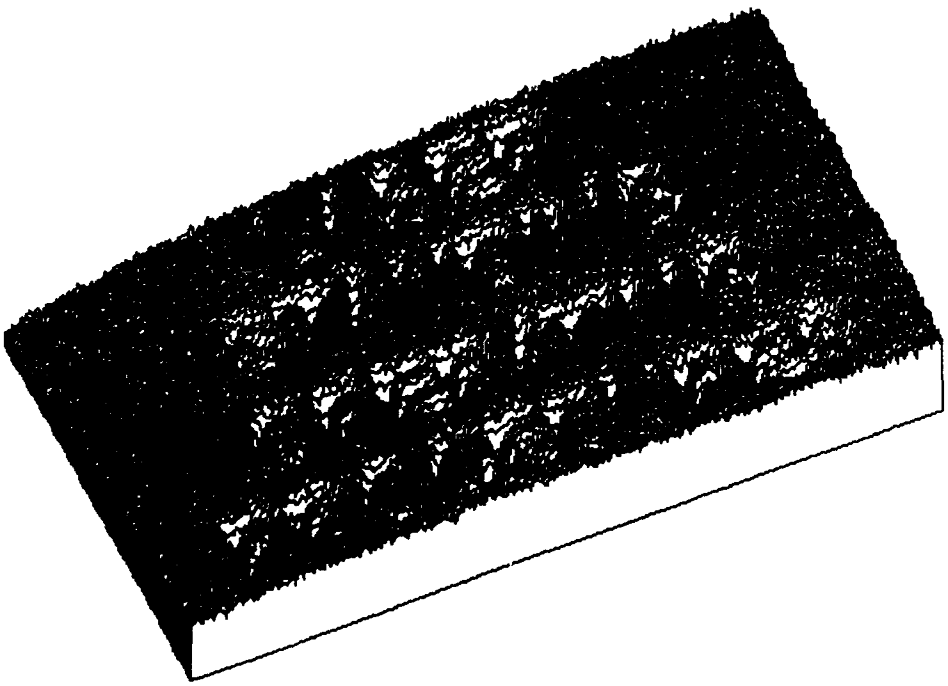

Figure 10. Spatial Profile of Target with Circular Hole Screen Filter in Front of Camera Lens

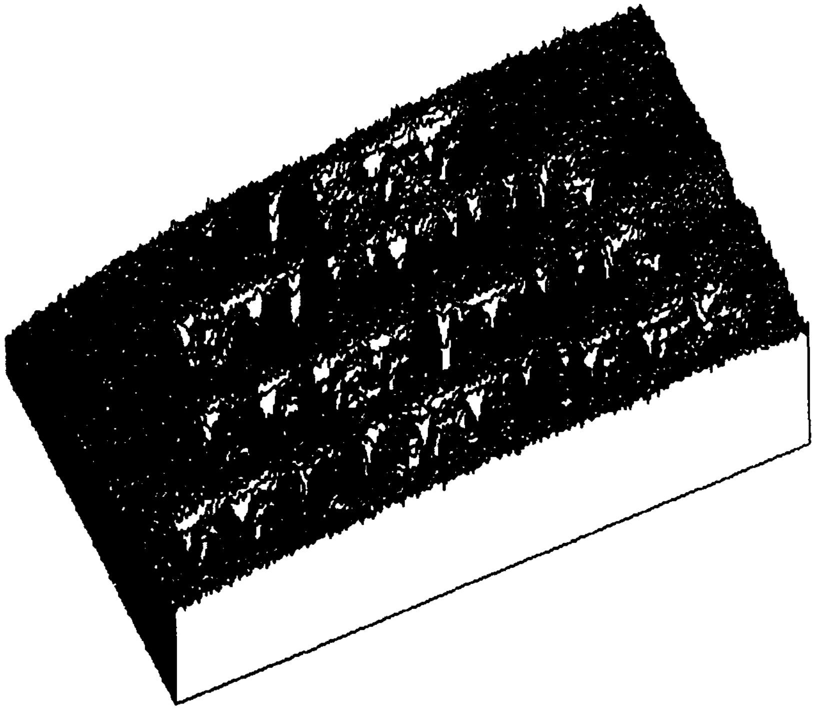

Figure 11. Spatial Profile of Target with Rectangular Hole Screen in Front of Camera Lens

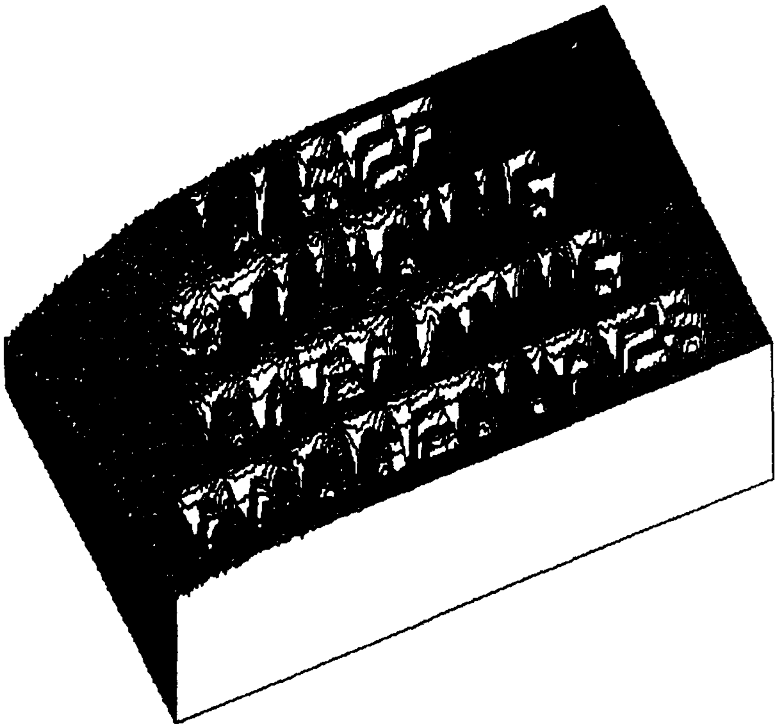

Figure 12. Spatial Profile of Target with "Dip" Etched Filter in Front of Camera Lens

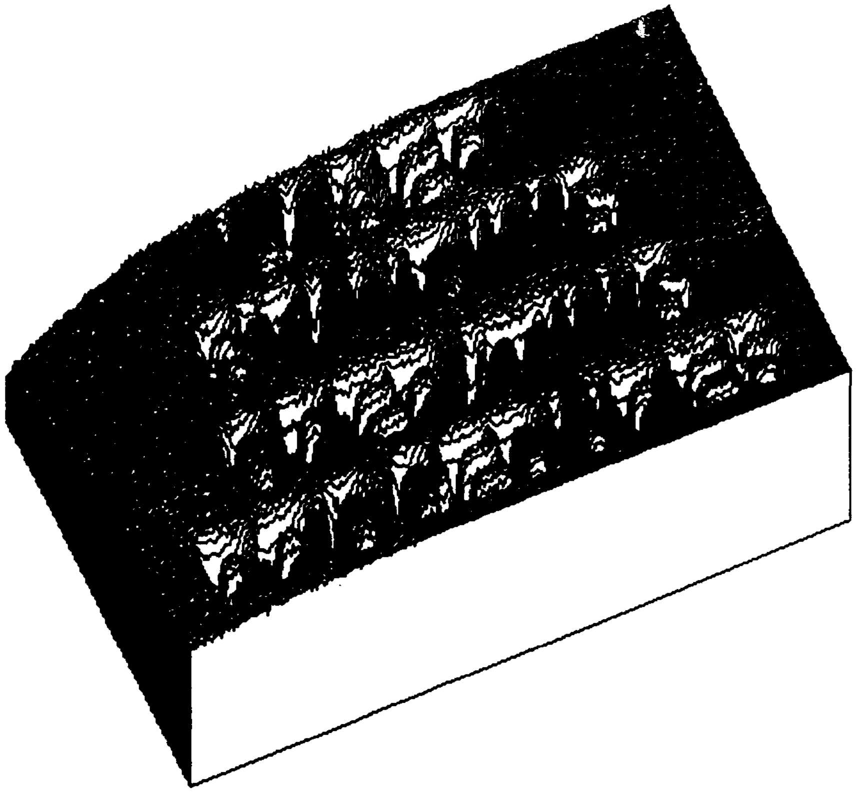

Figure 13. Spatial Profile of Target with "Masked" Etched Filter in Front of Camera Lens

IV. CONCLUSION

Preliminary experiments demonstrate that the intensity of a laser beam at the Fourier transform plane can be greatly reduced by placing a phase aberrator in the optical path before the transform lens. Filters consisting of circular and rectangular hole screens created a uniform attenuation of about 50 percent in the power density at the transform plane. A glass slide that was dipped 15 times in a 24 percent hydrofluoric acid and water solution reduced the power density at the transform plane by a factor of approximately 10. A filter etched with the acid solution in such a way as to create an index of refraction that varies as $n(x,y)=comb(x,y)circ(x,y)$ also reduced the intensity of the laser beam by a factor of about 10 at the transform plane.

It was also discovered that phase aberrators can be designed which do not impair one's vision more than is acceptable for certain tasks where visual acuity is essential. These results offer some promise in the possibility of successfully designing laser protective eyeware that will effectively reduce the possibility of serious eye damage due to a laser beam being focussed on the retina. Also, a major advantage of phase aberrator type protective eyeware is that it would be effective over the entire visible spectrum, not just small portions of the spectrum as is the case with existing eyeware.

REFERENCES

1. Otto, William F., personal communication, U.S. Army Missile Command, June 1988.

2. Goodman, J.W., *Introduction to Fourier Optics*, McGraw-Hill, New York, p. 22 (1988)

3. Gaskill, J.D., *Linear Systems, Fourier Transforms, and Optics*, John Wiley and Sons, Inc., New York, p. 70 (1978).

DISTRIBUTION

	Copies
Director U.S. Army Research Office ATTN: SLCRO-PH P. O. Box 12211 Research Triangle Park, NC 27709-2211	1
Headquarters Department of the Army ATTN: DAMA-ARR Washington, DC 20310-0623	1
Headquarters OUSDR&E The Pentagon Washington, DC 20310-0623	1
IIT Research Institute ATTN: GACIAC 10 W. 35th Street Chicago, IL 60616	1
U. S. Army Materiel System Analysis Activity ATTN: AMXSY-MP (Herbert Cohen) Aberdeen Proving Ground, MD 21005	1
AMSMI-RD-CS-T	1
AMSMI-RD-CS-R	15
AMSMI-GC-IP, Fred Bush	1
AMSMI-RD, W. McCorkle	1
R. Rhoades	1
AMSMI-RD-WS, W. Wharton	1
J. Bennett	1
S. Troglen	1
AMSMI–RD–WS–LS, Travis S. Taylor	10
Wayne E. Davenport	10
Stanley P. Patterson	10